PASSAGE 4

How Will Melting Ice Sheets Affect Us?

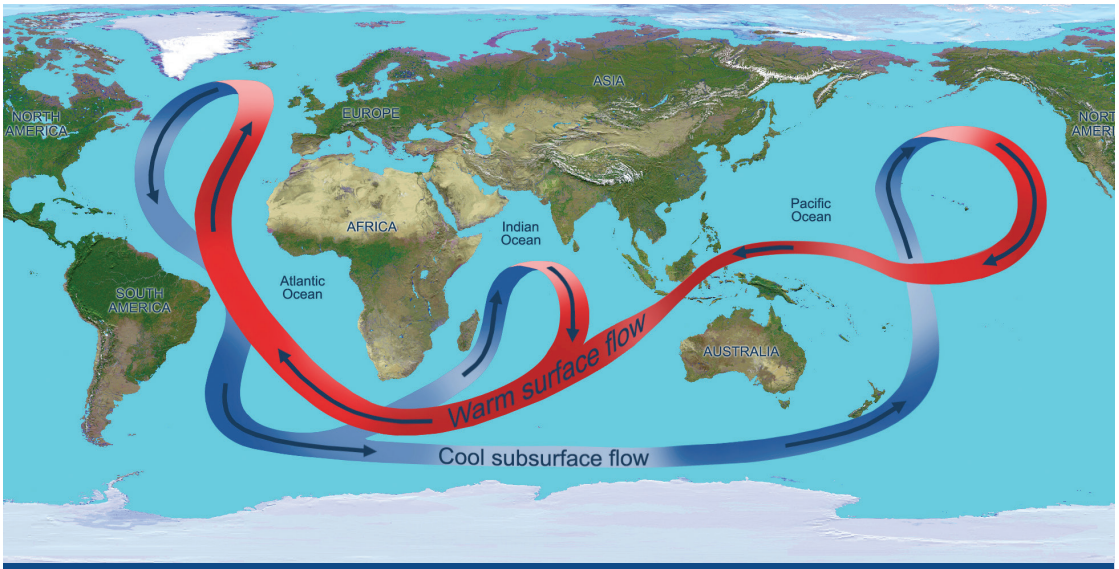
Variation is normal. During the last ice age, for example, ice sheets also covered much of North America and Scandinavia. Why is what's happening now different from what happened in the past? "It's different because we are adding an additional factor: extra warming," says geophysicist Isabella Velicogna. "We have a trend in temperature that doesn't look like it's going to slow down or stop." As she points out, many changes that have occurred cannot be reversed. "Once the mountain glaciers disappear, they're gone. Once it becomes so warm that no more sea ice forms in the summer, sea ice will form only in the winter and it won't be thick enough to last through the summer."

So far the effect has been small, and "maybe it will continue that way for the next ten years," says Velicogna. "The full effects of ice shelves breaking are difficult to predict. But even at present rates, a big part of Greenland will be gone by 2100 for sure, and probably also a big part of Antarctica. Nature has shown us that things can happen very, very fast." We do know that land ice affects many Earth systems, and that its loss will have a huge impact across the globe.

Climate will be affected by changes in ocean circulation and albedo

Ocean circulation: There is a system of deep-ocean currents that is constantly moving. It is called the global ocean conveyor belt (see figure on page 16). It is driven by differences in density in ocean waters. These differences in density are created by temperature and salinity. Cold water is more dense than warm water. Salt water is more dense than fresh water.

Warm water holds more salt. The Gulf Stream, which flows northward along the eastern coast of North America, is warm and salty. Around Greenland, these warm salty waters merge with the cold waters flowing south from the Arctic. The collision produces a huge amount of cold, salty water that is dense enough to sink to great depths. This deep current spreads southward along the bottom of the Atlantic all the way to the Southern Ocean.



The global ocean conveyor belt circulates the surface and deep sea (subsurface) currents over incredible distances.

Image source: **NASA**

Large-scale ocean circulation plays a very important role in Earth's climate. This is because it transfers huge quantities of heat around the globe. Ocean circulation usually stabilizes climate over hundreds to thousands of years. However, it may also cause abrupt changes in climate. Past climate records show that the circulation system may have occasionally slowed or stopped, then restarted abruptly (within a few years). This abrupt change may have had something to do with rapid and dramatic shifts in climate experienced by Greenland, northern Europe, and other places in the North Atlantic over the last 75,000 years.

A massive influx of fresh water from the ice sheets melting may affect this balance, possibly disrupting current climate again.

Albedo: In Passage 1 we learned that albedo is a measure of how reflective Earth's surface is. Ice, especially when it has snow on top of it, has a high albedo and reflects a lot of sunlight back into space. That's how land ice in polar regions helps keep the planet cool. Land and water, on the other hand, are darker and have a lower albedo. For example, the ocean reflects only six percent of the incoming sunlight while sea-ice with snow on it reflects 90%.

As sea ice shrinks, darker water is exposed, absorbs more sunlight, and heats up. This creates a **feedback loop**: a response to a change that influences the change itself. Less ice increases warming, which melts ice faster, which increases warming, and so on.

Rising sea level poses challenges never faced before

Mountain glaciers all over the world are melting. Although they are small and therefore do not hold much water, they provide fresh water to local communities and their loss is devastating. The Greenland and Antarctic Ice Sheets, on the other hand, hold massive amounts of water. The direct consequence of these ice sheets melting will be sea level rise.

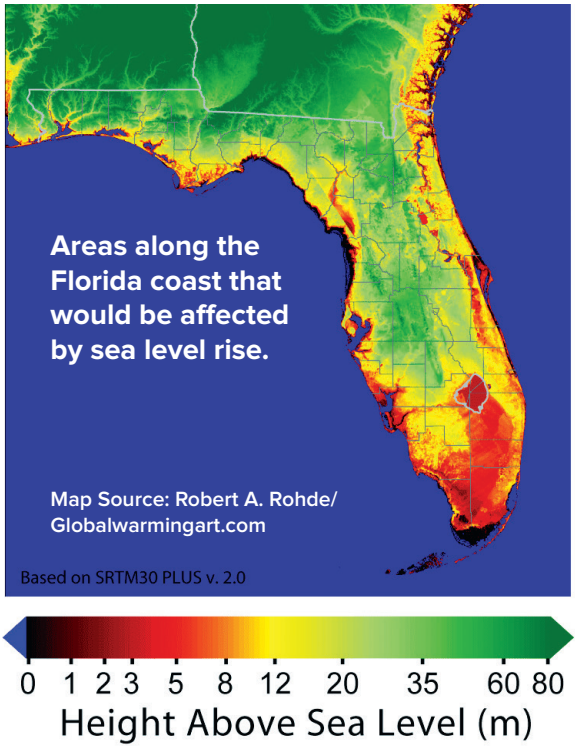
Estimating the amount of sea level rise—and the effects

We learned from GRACE that the melting of the Greenland and Antarctic Ice Sheets between 2002 and 2009 would correspond to about an 11 centimeter (a little over 4 inches) rise in sea level in a century if the ice continued to melt at the same rates. However, the rates of ice loss have been increasing. As a consequence, the rate of sea level rise has also been increasing. Based on this trend, sea level rise over the next century would be more than 11 centimeters.

Some estimates indicate that sea levels could rise as much as two meters by the year 2100, although most estimates are lower and all are highly uncertain. This would be enough to submerge large areas of coastline around the world. As Velicogna puts it, "One meter of sea level rise affects not only the coast but 10 kilometers (about 6 miles) inland. The surface is going to change, the vegetation is going to change, the animals that live there are going to change." Ecosystems will have to rapidly adapt, and massive numbers of people will be displaced.

Ten percent of the world's population lives in coastal regions within a 10-meter (33-foot) elevation of sea level. Most of the world's largest cities are at or near sea level, including New York, Miami, New Orleans, Bangkok, Shanghai, and Kolkata. Rising oceans threaten entire nations, including the Netherlands, the Maldives, and much of Bangladesh. A sea level rise of just 0.5 meters (1.7 feet) in a century would cause flooding due to coastal erosion, and flooding caused by storm surges and unusually high tides. By the end of the 21st century the number of people worldwide who live along coastlines less than 5 meters above sea level is estimated to increase from 200 million to 400-500 million.

The Greenland Ice Sheet holds enough ice to raise sea level by seven meters if it melted completely. This is enough of a rise to submerge most of Florida. If the West Antarctic Ice Sheet melted completely, it would raise the sea level by five meters.



The East Antarctic Ice Sheet, if it melted completely, would raise it another five. A sea level rise of 10 meters (33 feet) would flood areas where 25 percent of the U.S. population currently lives, mostly in the Gulf and East Coast States. If both ice sheets melted completely it would raise sea level by over 75 meters (almost 250 feet). These extreme changes are unlikely and if they occurred would take centuries, but need to be taken into consideration.

Satellite data will become critically important for managing Earth's water

Can ecosystems adapt? What will the consequences of displacing hundreds of millions of people be? What will it cost? We have no answers unless we can estimate the rate and amount of sea level rise. That's where GRACE, along with future data-collecting technologies, comes in.

Climate change unfolds over decades, centuries, millennia. "We need three, four, five decades of this kind of information to truly understand the behavior of Earth's water," says Famiglietti. While GRACE's satellites likely won't last that long, climate scientists hope future missions will keep the water data flowing. Having this incredibly important data could be essential in the effort to anticipate and manage the consequences of climate change for people worldwide. "The problem isn't which factors are natural and which are not," says Veligogna. "The problem is the consequences."

PASSAGE 4

Stop and Think Questions

Based on the Text

1. What are some possible consequences of the loss of land ice from Greenland and Antarctica?

2. Think about all four passages and the science practices listed below. How does the investigation of ice sheets in Greenland and Antarctica using the GRACE satellites provide examples of how scientists work?
   - Asking questions
   - Developing and using models
   - Planning and carrying out investigations
   - Analyzing and interpreting data
   - Using mathematics and computational thinking
   - Constructing explanations
   - Engaging in argument from evidence
   - Obtaining, evaluating, and communicating information

3. What actions do you think can be taken to minimize the effects of metling ice sheets in Greenland and Antarctica?